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NAVAL AEROSPACE MEDICAL RESEARCH LABORATORY

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**WORK/REST SCHEDULES AND  
PERFORMANCE OF F/A-18  
AVIATORS DURING FLEET  
EXERCISE 1992**

Scott A. Shappell and David F. Neri

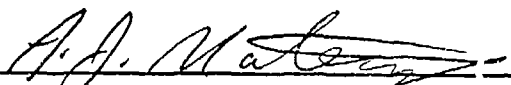
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## ABSTRACT

As a continuation of our previous work during Operation Desert Shield/Storm, we examined the effect of a fleet exercise on the work/rest patterns, fatigue and cognitive performance of F/A-18 aviators. For 10 days during Fleet Exercise 1992, 25 pilots from VFA-81 and VFA-83 completed daily work/rest logs while performing their usual tasks. Subjective measures of fatigue, quality of rest, and sleep need were also collected. A subset of these F/A-18 pilots completed a brief battery of cognitive tasks as soon before flying as possible and again after the flight debrief. As a group, the pilots were adequately rested, with little or no problem sleeping and operated on a typical work/rest schedule for deployed F/A-18 aviators. However, in some instances during which late night missions were flown, sleep onset was delayed, coupled with shorter sleep periods and additional sleep problems. Several work/rest and flight-related parameters were related to subjective measures of aircrew combat readiness, including: 1) flight quartile, 2) number and order of flights per day, 3) flight duration, 4) flight hours 72 h before a mission, 5) total work 24 h before a mission, 6) total sleep 12 h before a mission, and 7) total hours continuously awake before a mission. All seven variables significantly contributed to a multiple regression model derived using subjective strike delay, accounting for 51% of the variance. Moreover, statistically significant changes were observed from pre- to postflight on a fatigue-sensitive reaction-time task. These data provide a valuable metric for battlegroup and airwing commanders, squadron commanding officers, senior mission planners, and flight surgeons when assessing combat readiness among aircrew, ultimately enhancing the safety of flight.

## Acknowledgments

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## INTRODUCTION

Aircraft carrier based naval aircrews train for, and may be called on to engage in, combat operations requiring long periods of continuous performance interrupted by shorter periods of sustained performance. The nature of combat operations aboard an aircraft carrier often require many hours of mission planning and briefing by the same aircrew who later fly into combat. This 'front-loading' of naval aviators during a period of continuous performance may last several hours to days and is only a prelude to the sustained performance required in the cockpit while actually flying the mission. In many instances, aviators are required to sustain performance beyond the initial mission flown to include additional missions before opportunities for crew rest are made available. Any investigation of carrier-based naval aircrews should include both the front-loading attributed to continuous operations (CONOPS) and subsequent sustained operations (SUSOPS) associated with the mission tasking itself.

Numerous reports characterize the effects CONOPS/SUSOPS have on combatants [for an annotated bibliography, see Krueger & Barnes (1989), for a review see Krueger (1990)]. Perhaps most compelling are fatigue and stress, which ultimately limit operational readiness. Although fatigue in combat is well documented, when CONOPS/SUSOPS are applied to a naval aviation scenario, the prospects of a negative outcome become considerably more complex. Even when naval aviators are not engaged in combat-related CONOPS/SUSOPS, they are not free to rest in preparation for the next event. Rather, they are often required to perform numerous collateral duties, requiring long periods of work, separated by erratic opportunities for rest. The nature of such operations aboard an aircraft carrier frequently disrupts normal sleep patterns, often exacerbating stress and fatigue experienced by combat aircrews. Further complications result when carrier-based aircraft are launched and recovered on flight decks a fraction the size of a conventional landing strip. Moreover, many aircraft recoveries occur at night, confounded by adverse weather conditions and a pitching flight deck, which all combine to make visual cues minimal at best. Any one, or combination of these factors, may combine with high-workload schedules to impair aircrew performance and impact negatively on operational readiness.

Aircrew fatigue is not limited to CONOPS/SUSOPS. We have recently published a series of detailed reports documenting work/rest schedules (Neri & Shappell, 1992), aircrew readiness (Shappell & Neri, 1992), and reported fatigue (DeJohn, Shappell, & Neri, 1993) experienced by A-6 and F-14 aircrews aboard USS AMERICA during Operations Desert Shield/Storm. Operations aboard USS AMERICA can best be described as cyclical. These cyclical operations (CYCLOPS) consisted of 4 d of combat and support missions followed by 2 d of crew rest. This was an idealized schedule since modifications were often made as operational demands required. That is, not every member of the squadron flew 4 consecutive days followed by 2 d of rest. Some flew less. Rarely did aircrew fly more than 4 consecutive days. The 2 d of rest were not obligatory either. Actual days off varied from 1 to 3 d, depending on operational demands.

On the surface, a 4-d on/2-d off CYCLOPS would appear manageable and not particularly fatiguing. However, several conditions make this appearance inaccurate. First, these were combat missions flown over hostile territory where stress was high and combat losses, though few, did occur. Second, combat missions were unusually long in duration and often occurred between 2200-0400, a time when aircrew would otherwise be asleep. Third, mission planning, briefing, and debriefing were extensive. Fourth, in some instances, aircrew flew more than one mission per day, although there were few instances of sustained/continuous performance beyond 24 h. Fifth, although aircrew engaged in combat operations, the everyday administrative load still remained with several hours per day being devoted by aircrew to collateral duties. Days during which no combat mission was flown could not be devoted to rest and relaxation in preparation for the next cycle of combat missions. Rather they were often used to plan the next combat strikes and to catch up on administrative tasks. Taken together, mission planning, briefing and debriefing, duration and timing of combat missions, and administrative burdens provided ample sources of fatigue even during these seemingly manageable CYCLOPS.

In addition to adding CYCLOPS to the list of combat operations capable of producing fatigue in aircrew, the study conducted aboard USS AMERICA was unique in other ways. First, this was the first systematic documentation of the same aircrew's work/rest schedules during peacetime and combat aboard an aircraft carrier. Second, it represented the first formal documentation of fleet aircrew fatigue related to work/rest schedules and mission tasking. Finally, it comprised the only data obtained from fleet aviators engaged in combat operations during the Persian Gulf War. Still, the study aboard USS AMERICA was envisioned as a first step in a much larger investigation of combat aircrews aboard naval aircraft carriers.

Interviews with airwing commanders and squadron commanding officers, and our own observations indicate that by only obtaining data from F-14 and A-6 squadrons we may have missed the heavier-tasked F/A-18 squadrons. We attempted to collect data from one of two F/A-18 squadrons aboard USS AMERICA, but operational tasking prompted them to withdraw very shortly after the beginning of Operation Desert Storm. Therefore, the next step was to extend and replicate the results obtained aboard USS AMERICA to include the entire aircraft carrier airwing (one squadron each of A-6, EA-6, S-3, E-2 and SH-3, and two squadrons each of F/A-18s and F-14s). Because data collection during actual combat operations is rare, we sought a suitable alternative. The U.S. Navy frequently conducts fleet exercises lasting 10-20 d to simulate real-world conflicts. These exercises are intended to simulate combat operations and are conducted against fleet adversaries. Although fleet exercises do not provide all the life and death stressors of actual combat, they are an excellent compromise to data collection during combat operations. This assertion is supported by anecdotal reports given by aircrew aboard USS AMERICA that suggest the fleet exercises prepared them for combat in the Persian Gulf. In fact, many of these same aircrew felt that refresher training operations and fleet exercises were more fatiguing than actual combat in the Persian Gulf.

## METHODS

Data were collected from aircrew assigned to all elements of the carrier airwing. However, interviews with airwing commanders and our own experience aboard USS AMERICA led us to dedicate a single report to aviators assigned to the F/A-18 Hornet, a group that was particularly fatigued during Operation Desert Shield/Storm. Data reported here will be from F/A-18 pilots only. The remainder of the data is reported elsewhere (Neri & Shappell, 1993).

The specific objectives of this report are to:

- 1) Document F/A-18 pilot work/rest cycles and the quality of crew rest.
- 2) Identify any variables related to F/A-18 pilot combat readiness.
- 3) Identify any mission specific differences in pilot combat readiness.
- 4) Determine if any preflight/postflight differences in combat readiness exist.
- 5) Quantify the extent to which selected variables relate to F/A-18 pilot combat readiness using multiple regression techniques.
- 6) Evaluate the effect of flying on F/A-18 pilot performance using objective means.

Toward these ends, all pilots completed a daily activity survey including questions regarding the quality of sleep, combat readiness, and fatigue in the cockpit. Additional data identifying operational tasking were obtained from squadron operations officers. Objective testing of aviators was done using the performance test described below.

## SUBJECTS

Aircrew were recruited from two F/A-18 Hornet squadrons (VFA-81 and VFA-83) assigned to Carrier Air Wing 6 deployed aboard USS SARATOGA (CV-60). The U.S. Navy version of the F/A-18 is a single-seat dual-role fighter/attack aircraft requiring only a pilot to complete its mission. The experimental subjects

included 25 F/A-18 pilots (15 from VFA-81 and 10 from VFA-83). All pilots were routinely briefed on the voluntary nature of the study and permitted to withdraw at any time without prejudice.

## PROCEDURE

### General

The study was conducted aboard USS SARATOGA (CV-60) from 31 January through 09 February 1992. During this time, the ship was participating in a fleet exercise off the coast of Puerto Rico. All pilots completed a daily activity survey and subjective sleepiness inventory pre- and postflight. A subset of these pilots also completed a battery of computer-administered cognitive tasks.

### Activity Survey

The activity survey (Fig. 1) was a modification of the one used aboard USS AMERICA during Operations Desert Shield/Storm (Neri & Shappell, 1992; Shappell & Neri, 1992), and modeled after Hartman and Cantrell (1967), Storm (1980), and Naitoh, Banta, Kelly, Bower, and Burr (1990). Activity surveys of this type have been used to predict task performance and mood (Beare, Bondi, Biersner, & Naitoh, 1981) and have been shown to produce reliable sleep measures (Naitoh, et al, 1990). Pilots were instructed to indicate their activity on the survey to a resolution of 0.5 h by marking in the appropriate box the letter corresponding to the activity they engaged in during that block of time. A complete list of activities and their associated codes can be found in Table 1. Pilots typically entered information on the survey one-two times per day, accounting for several hours at a time.

ACTIVITY SURVEY																								
SUBJECT:												DATE:				TIME:								
1. ON THE CHART BELOW, MARK THE APPROPRIATE LETTER IN EACH HALF HOUR INTERVAL																								
KEY: A=ALERT    M=MEALS    B=BRIEF    C=COLLATERAL DUTIES    R=RECREATION/REST    E=EXERCISE S=SLEEP    F=FLIGHT    D=DEBRIEF    P=STRIKE PLANNING    G=GO/DRILLS    X=TESTING																								
DATE _____																								
← MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	← MID-NIGHT
DATE _____																								
← MID-NIGHT	0100	0200	0300	0400	0500	0600	0700	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	← MID-NIGHT
2. HOW MUCH TROUBLE DID YOU HAVE SLEEPING DURING PERIOD:																								
1st Period)		<input type="checkbox"/> NONE		<input type="checkbox"/> SLIGHT		<input type="checkbox"/> MODERATE		<input type="checkbox"/> CONSIDERABLE		<input type="checkbox"/> DID NOT SLEEP														
2nd Period)		<input type="checkbox"/> NONE		<input type="checkbox"/> SLIGHT		<input type="checkbox"/> MODERATE		<input type="checkbox"/> CONSIDERABLE		<input type="checkbox"/> DID NOT SLEEP														
3. HOW RESTED DID YOU FEEL UPON AWAKENING DURING PERIOD:																								
1st Period)		<input type="checkbox"/> WELL RESTED		<input type="checkbox"/> MODERATELY RESTED		<input type="checkbox"/> SLIGHTLY RESTED		<input type="checkbox"/> NOT AT ALL		<input type="checkbox"/> DID NOT SLEEP														
2nd Period)		<input type="checkbox"/> WELL RESTED		<input type="checkbox"/> MODERATELY RESTED		<input type="checkbox"/> SLIGHTLY RESTED		<input type="checkbox"/> NOT AT ALL		<input type="checkbox"/> DID NOT SLEEP														
4. DO YOU FEEL LIKE YOU COULD HAVE USED SOME MORE SLEEP? <input type="checkbox"/> YES <input type="checkbox"/> NO																								
5. IF YOU HAVE FLOWN DURING THIS PERIOD, HOW SOON AFTER YOUR LAST FLIGHT COULD YOU HAVE FLOWN A STRIKE? _____ HRS																								
6. HOW MUCH TROUBLE DID YOU HAVE STAYING AWAKE WHILE FLYING?																								
1st Flight)		<input type="checkbox"/> NONE		<input type="checkbox"/> SLIGHT		<input type="checkbox"/> MODERATE		<input type="checkbox"/> CONSIDERABLE		<input type="checkbox"/> SLEPT DURING PORTION OF FLIGHT														
2nd Flight)		<input type="checkbox"/> NONE		<input type="checkbox"/> SLIGHT		<input type="checkbox"/> MODERATE		<input type="checkbox"/> CONSIDERABLE		<input type="checkbox"/> SLEPT DURING PORTION OF FLIGHT														
7. HOW MANY CUPS OF COFFEE OR CAFFEINATED SOFT DRINKS DID YOU INGEST DURING THIS PERIOD? _____																								

Figure 1. The activity survey.

Table 1. Activity Survey Code Definitions.

Category	Code	Definition
Alert	A	Alert flight status, ready to launch in short time
Sleep	S	Time actually asleep
Meals	M	Eating
Flight	F	Time in the aircraft and airborne
Brief	B	Briefing for the upcoming flight
Debrief	D	Debriefing after completion of a flight
Collateral Duties	C	All official duties other than flight-related activities
Strike Planning	P	Planning the upcoming mission(s)
Recreation/Rest	R	Time not flying or working on other official duties
GQ/Drills	G	General quarters or duties associated with other drills
Exercise	E	Exercising in stateroom or small workout area
Testing	T	Time spent participating in cognitive testing

In addition to the activity data, several questions regarding sleep quality, restedness, caffeine intake, subjective combat readiness, and difficulty staying awake in the cockpit were included. Items 2, 3, 4, and to a lesser extent 7, addressed the quality of sleep, overall restedness, and any artificial means of resisting fatigue. Perhaps more important to senior mission planners and squadron commanding officers are items 5 and 6 of the activity survey. Item 5, "If you have flown during this period, how soon after your last flight could you have flown a strike?" is an index of how much rest aircrew felt they needed before a combat strike could be successfully flown. It was emphasized to all pilots that this was not just any flight, but an actual combat strike. We refer to data obtained from item 5 as aircrew subjective strike delay (SSD). Item 6 was included due to informal interviews of aircrew returning from combat during Operation Desert Shield/Storm. At least for those F-14 and A-6 aircrew included in our previous study, many had difficulty staying awake in the cockpit during the long transit from the combat area back to the aircraft carrier. In fact, in some instances, aircrew reported sleeping in the cockpit. To address this issue, we added item 6, "How much trouble did you have staying awake while flying?"

Specific flight and flight-related information was obtained by comparing the activity survey flight data with the flight scheduling information provided by the squadron operations officers. Flight data included 1) launch and recovery times, 2) flight duration, 3) mission assignment, 4) number and order of flights flown each day, 5) number of flight hours 72 h before a flight, 6) number of hours spent working 24 h before a flight, 7) amount of sleep 12 h before a flight, and 8) the flight-time quartile. Most of these variables are self-explanatory; however, flight-time quartile requires some explanation. To evaluate if time of day had any effect on SSD, each day was partitioned into four equal flight-time quartiles: quartile 1 - 0601 through 1200, quartile 2 - 1201 through 1800, quartile 3 - 1801 through 2400, and quartile 4 - 0001 through 0600. If a flight spanned more than one quartile, assignments were made on the basis of that quartile during which the majority of the flight occurred.

### **Subjective Sleepiness Inventory**

On the back of each card a subjective questionnaire, the Stanford Sleepiness Scale (SSS), was completed before each flight (preflight) and after each mission debrief (postflight). The SSS is used to determine how sleepy subjects feel (Hoddes, Dement, & Zarcone, 1971). It consists of a series of seven numbered statements ranging from *Feeling active and vital; alert; wide awake* to *Almost in reverie; sleep onset soon; lost*



*struggle to remain awake.* Pilots indicated how sleepy they were at that time by checking the appropriate box next to their response.

### ***Computer-administered Cognitive Tasks and Subjective Inventories***

In addition to completing the activity survey, seven pilots from VFA-81 completed a 5-min battery of computer-administered cognitive tasks approximately 30 min before the mission and again after the mission debrief. By strategically positioning the cognitive tasks in this manner, we could obtain an objective assessment of mission fatigue. Cognitive testing was included as a part of the mission debrief, far enough in time from the actual landing so that the increased alertness and 'adrenalin rush,' present after an aircraft carrier recovery, would not interfere with the data.

The cognitive task was composed of blocks 1 and 5 of the Reaction Time (RT) task of the Advisory Group for Aerospace Research & Development (AGARD) Standardized Tests for Research with Environmental Stressors (STRES) Battery (Aerospace Medical Panel Working Group 12, 1989). The RT task has demonstrated sensitivity to fatigue and sleep loss, as well as other factors (Aerospace Medical Panel Working Group 12, 1989). Block 1 is the basic block of trials. Pilots used the index and middle fingers of both hands to press keys on the keyboard in response to stimuli presented on the computer screen. The basic block is a choice reaction-time procedure. Any number from 2 to 5 can appear on the screen, one at a time. If the number appears on the left side of the screen, pilots are instructed to respond with one of the two fingers of their left hand. If the number appears on the right side, they use one of the right-hand fingers. If the number is low (2 or 3) the pilots respond with the leftmost finger on the proper hand. If the number is high (4 or 5) they respond with the rightmost finger. The numbers are presented for 1 s followed by a blank screen for 1 s. The pilot is instructed to respond as soon as he sees the number. Speed of response is emphasized, but not at the expense of accuracy. A feedback message (the word *error*) appears on the screen when the subject makes an error or fails to respond within 2 s of the presentation of the number. The interval between successive presentations of the numbers is always at least 1 s.

Block 5 is the inverted block. It is similar to the basic block in all ways except the following. Stimuli appearing on the right-hand side of the screen require a left-hand key press, and stimuli appearing on the left-hand side of the screen require a right-hand key-press. The basic block was always presented first, followed by the inverted block. Trial blocks were about 2 min each in duration and consisted of about 60 trials, depending on the performance efficiency of the subject. Both reaction time and accuracy were recorded by the computer.

## **RESULTS**

### **DESCRIPTIVE STATISTICS**

#### ***Work/Rest Patterns***

By extracting the activity data from item 1 of the survey, we could reconstruct the average time pilots spent at work and rest during the fleet exercise. Work was subdivided into three categories: 1) flight time, 2) flight-related activities, and 3) other work. Flight time is self-explanatory and included all codes of "F" on the activity survey. Flight-related activities included all other codes associated with a specific flight including preflight mission briefing (indicated by a "B" on the activity survey), postflight mission debriefing (D), and any alerts (A). Other work included all other job-related activities including mission planning (P), collateral duties (C), cognitive testing (X), and general quarters drills (G). Crew rest was subdivided into sleep and other rest activities. Sleep included all codes of "S" whether they occurred during the major sleep period (i.e., the longest period of consecutive sleep in a 24-h period) or during a nap. The major sleep period is described in more detail below. Other rest included recreation (R), meals (M), and exercise (E). A

complete listing of the percentage of time pilots spent engaged in activities listed on the survey is presented in Table 2.

Table 2. Hours Spent Engaged in Each Activity During Each Day of the Fleet Exercise.

Day	Activity Survey Codes												Missing
	A	S	M	F	B	D	C	P	R	G	E	X	
1	0.15	7.74	1.20	1.30	1.29	0.22	7.53	0.09	2.27	0.41	0.28	0.15	1.37
2	1.35	6.87	1.19	2.02	1.58	0.42	7.43	0.04	1.39	0.00	0.55	0.11	1.05
3	1.44	6.67	1.07	1.17	0.76	0.31	7.59	0.50	1.56	0.09	0.26	0.02	2.56
4	2.02	6.34	1.02	1.84	1.22	0.52	5.70	0.30	1.48	0.00	0.24	0.11	3.19
5	1.17	5.92	1.10	2.91	2.27	0.59	4.04	0.21	0.90	0.00	0.11	0.10	4.69
6	1.72	7.07	0.98	1.09	1.31	0.29	6.50	0.05	1.19	0.21	0.14	0.11	3.33
7	1.55	6.00	1.19	3.00	1.73	0.88	5.60	0.42	1.00	0.00	0.07	0.21	2.65
8	1.64	6.22	1.06	2.22	1.30	0.73	5.67	0.03	2.08	0.00	0.25	0.17	2.64
9	0.78	7.28	1.06	1.42	1.63	0.42	8.83	6.39	1.39	0.00	0.31	0.06	1.05
10	0.04	7.40	1.20	0.11	0.54	0.00	9.00	1.93	1.74	0.54	0.31	0.00	1.20
11	0.25	7.70	1.25	0.50	0.55	0.15	6.60	1.55	2.35	0.00	0.15	0.00	2.96

The average time pilots spent working and at rest during the fleet exercise is illustrated in Fig. 2. Pilots spent between 9.5 and 13 h per day working (Fig. 2a). The majority of that time was spent engaged in work other than flying and flight-related duties. However, the data presented in Fig. 2 are means computed across both squadrons. Individual time spent in each work category may vary. Therefore, the observation that mean time spent flying on day 1 of the fleet exercise was a little more than 1 h does not mean that all pilots flew 1 h that day. Rather, some pilots flew missions of varying duration while others may not have flown at all. Average time spent resting ranged between 8-11.5 h, with the majority of this time spent asleep (Fig. 2b). Unfortunately, this figure does not portray how well aircrew slept or whether sleep was fragmented, both factors known to influence the refreshing nature of crew rest.

By extracting the sleep data (S) from completed activity surveys, we could reconstruct a profile of F/A-18 pilot sleep patterns. Mean onset and duration of the major sleep period is illustrated in Fig. 3. Pilots generally reported going to bed between 0000 and 0200 (Fig. 3a), averaging 6-8 h sleep per night (Fig. 3b). By inspection of Fig. 3, two, and possibly three, peaks are evident in the sleep onset data. Sleep onset was delayed to an average of 0100 to 0200 during days 2 and 3, days 7 and 8, and also day 11. This is particularly interesting because these are mean sleep onset times indicating that sleep onset in some instances was later than the mean reflected on the graph. Moreover, during many days when sleep onset was delayed (i.e., days 2, 7, and 8), total sleep duration decreased to roughly 6 h, slightly less than on other days of the fleet exercise. This delay in sleep onset, coupled with an overall reduction in total sleep, may have put the pilots at risk if missions were flown following such disruptions of normal sleep patterns. Risk to pilots would be exacerbated if these abnormal sleep periods were confounded by additional sleep disturbances during the major sleep period like excessive noise, heat, or other adverse shipboard environmental factors.

In general, few problems associated with sleeping were reported as reflected in items 2, 3, and 4 of the sleep survey (Fig. 4). Pilots reported *none* to *moderate* levels of trouble sleeping (Fig. 4a), were *well rested* to slightly less than *moderately rested* (Fig. 4b), and reported a need for additional rest (Fig. 4c). Closer inspection of Fig. 4 reveals at least one, and maybe two, distinct peaks present in the data. The most prominent peak occurred over days 7 and 8 of the exercise, as evident in all three panels of Fig. 4. During this period, pilots reported the most trouble sleeping, the least restful sleep, and the most need for additional

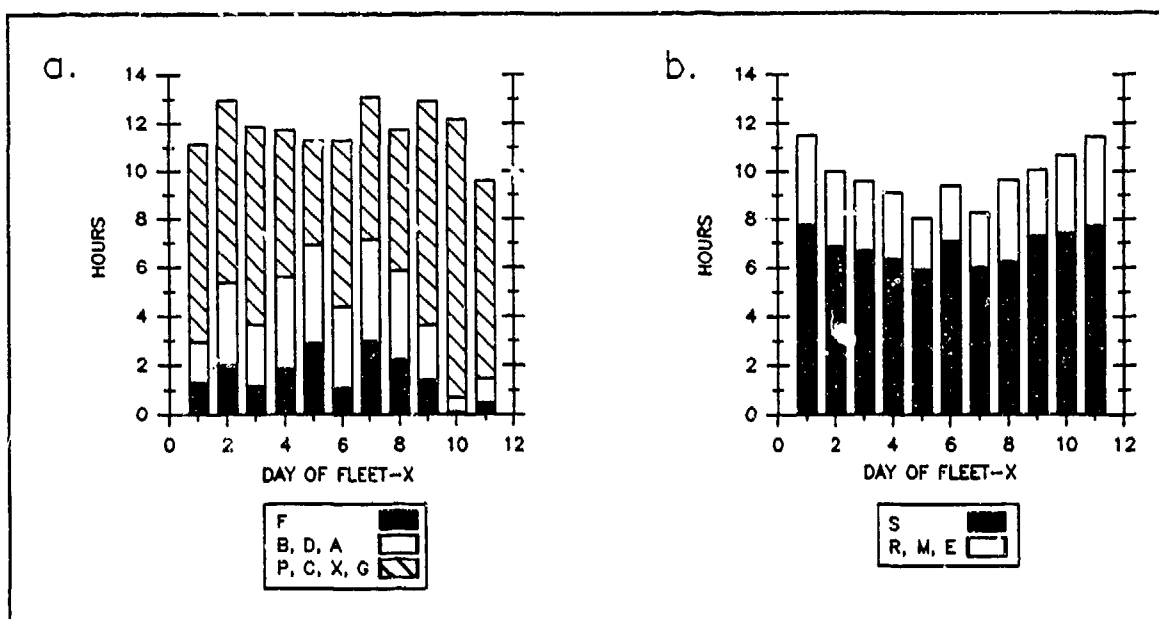


Figure 2. Pilot mean hours of work (a) and rest (b) plotted as a function of the day of the fleet exercise. Activity codes used to categorize work and rest are indicated in the legends below each panel.

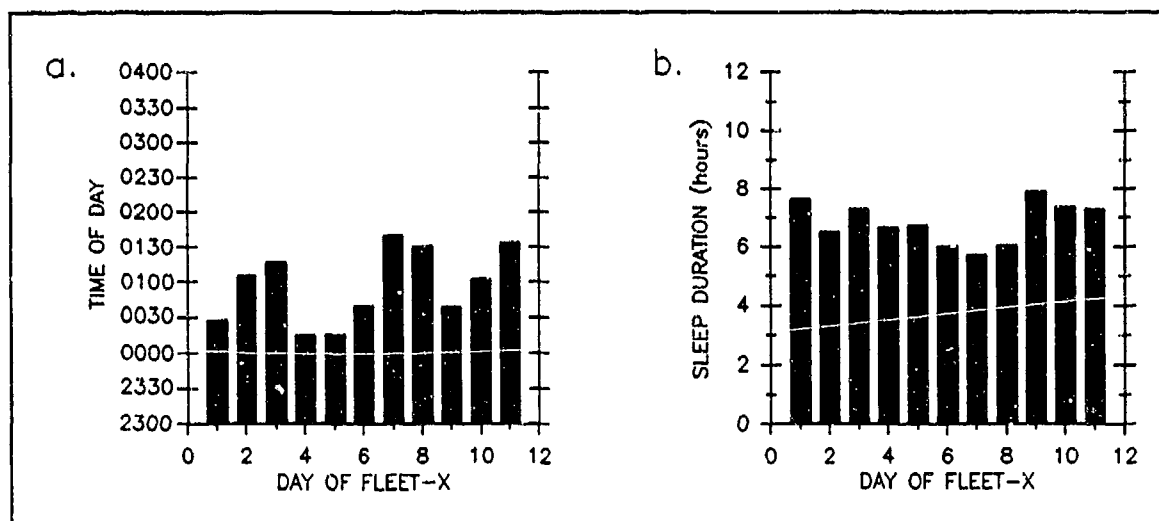


Figure 3. Pilot mean sleep onset (a) and sleep duration (b) plotted as a function of the day of the fleet exercise.

rest. This peak coincides with a delay in sleep onset coupled with a shorter duration of sleep as described for days 7 and 8 above. A second peak is evident in panel c during days 3-5 of the fleet exercise. However, it still appears in panels a and b, approaching a *slight* amount of trouble sleeping and *moderately rested*. This second peak is also coupled with a delay in sleep onset and shorter duration of sleep.

#### Activity Survey Item #5: Subjective Strike Delay

Pilot estimates of SSD following mission debrief are consistent with those obtained during Operation Desert Shield/Storm (Shappell & Neri, 1992). Figure 5 graphically depicts mean pilot SSD as a function of

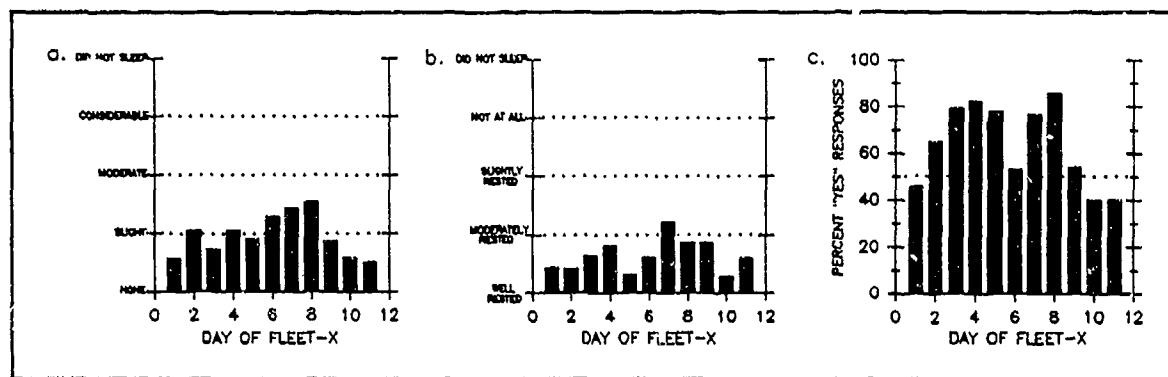


Figure 4. Population mean responses to sleep-quality questions on activity survey plotted as a function of day of the fleet exercise.

selected work/rest and flight parameters: a) flight quartile, b) number and order of flights in a day, c) flight duration, d) total flight hours 72 h before flying, e) total work 24 h before flying, f) total hours of sleep 12 h before flying, and g) total hours continuously awake before flying.

Mean reported SSD ranged from 1 to 10 h across all seven parameters examined and increased a) as flight quartile increased from the first (0601-1200 h) through the fourth flight quartile (0001-0600 h), b) following the second flight of the day, c) as flight duration increased, d) as the number of flight hours increased 72 h before a flight, and e) as the total number of hours working increased 24 h before a flight. Conversely, pilot SSD decreased as the total amount of sleep 12 h prior to flying increased. Reported SSD was much less complete (note the gap in the data at 4.5, 5.0, 7.0, 7.5, 8.0, and 8.5 h), yet appeared to increase as the total hours continuously awake before flying increased.

#### Activity Survey Item #6: Trouble Staying Awake in the Cockpit

Data obtained from item 6 of the activity survey, "How much trouble did you have staying awake while flying?" did not produce any meaningful variation when plotted against the seven work/rest and flight parameters examined. As a group, pilots reported *none* to *slight* difficulty staying awake in the cockpit. Individual responses did vary. However, the variation was much less than anticipated, with no pilot reporting more than *moderate* difficulty staying awake in the cockpit.

#### Stanford Sleepiness Scale

Pilots generally reported feeling *active and vital; alert; wide awake to a little foggy; not at peak; let down* both pre- and postflight (Fig. 6). As before, Fig. 6 represents group means, indicating that in some instances individual reports were higher than indicated in the figure, reaching states of sleepiness from *fogginess; beginning to lose interest in remaining awake; slowed down to prefer to be lying down; fighting sleep; woozy*. An examination of postflight reports on the SSS yielded mixed results. Where meaningful variation did occur, a pattern of results consistent with those obtained for item 5 (SSD) of the activity survey was evident. When reported sleepiness is plotted as a function of flight quartile, flight number, flight duration, and the number of flight hours logged 72 h before flying, an increasing trend is evident in the data both pre- and postflight. Not surprising, early morning flights (quartile 4), the second flight of the day, longer flight durations, and more flight hours 72 before a flight all yield higher SSS scores. However, little

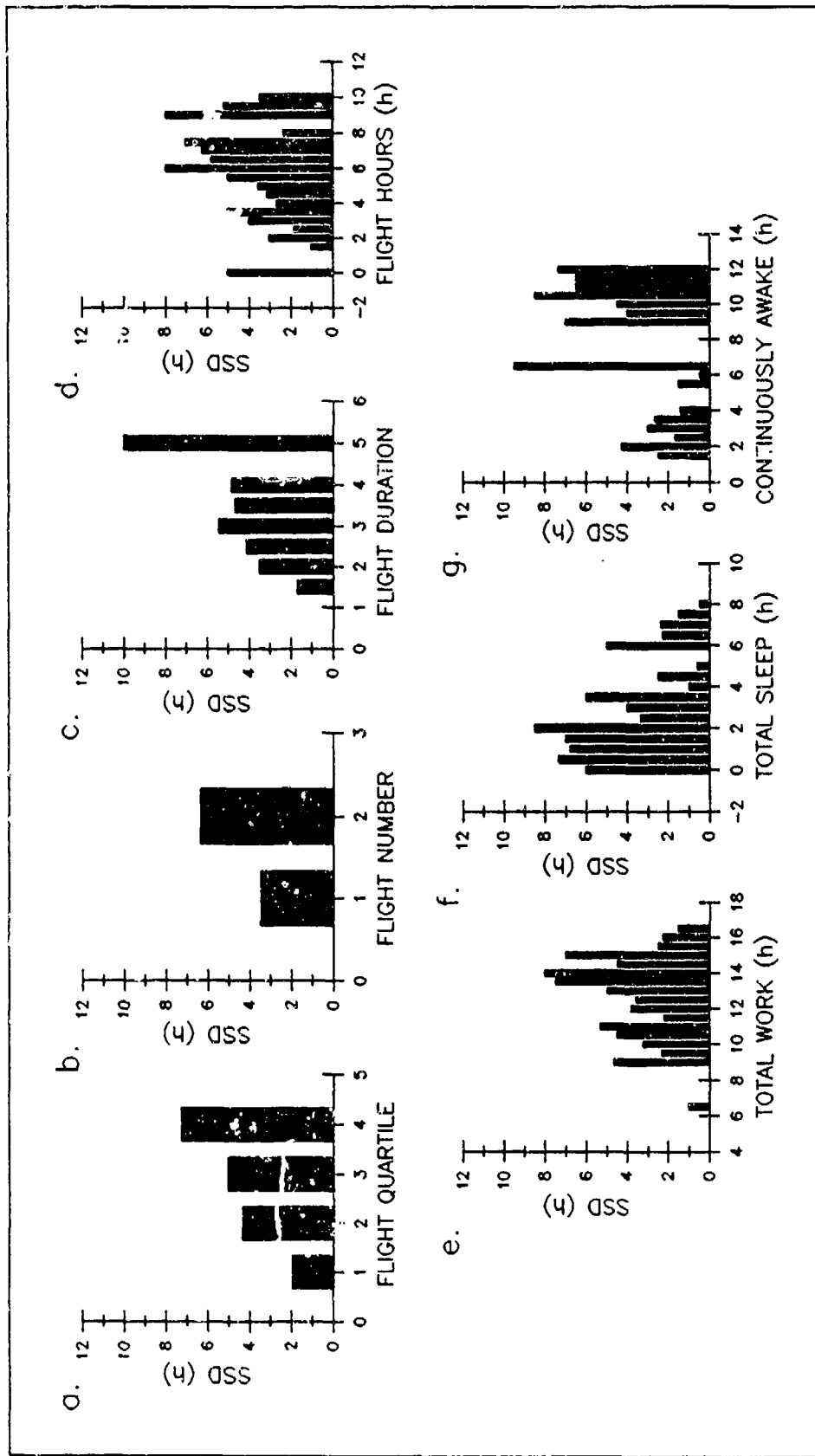


Figure 5. Pilot mean SSD plotted as a function of the seven experimental variables.

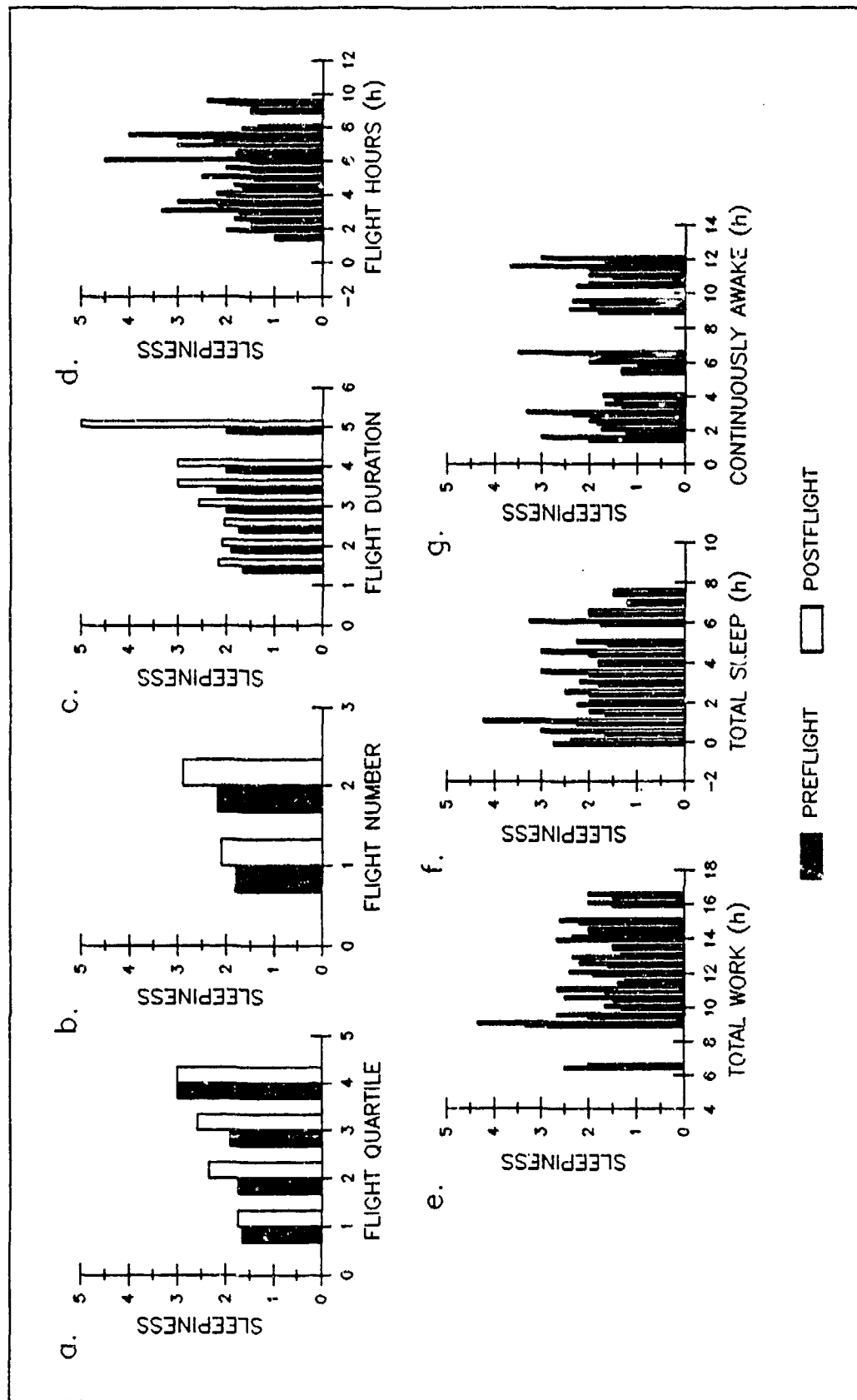


Figure 6. Mean pre- and postflight SSS scores plotted as a function of the seven experimental variables.

or no consistent variation is evident when reported sleepiness is plotted as a function of the total hours spent working 24 h before flying, the amount of time spent sleeping 12 h before flying, and the amount of time pilots spent continuously awake before flying.

By contrasting pre- with postflight reports on the SSS, the interaction of work/rest and flight parameters with the mission flown can be visualized. When preflight versus postflight differences did exist, postflight responses were typically higher, indicating a greater degree of sleepiness partially attributable to the mission flown. The effect was constant across all parameters examined.

### Mission Analysis

Based on data obtained aboard USS AMERICA during Operations Desert Shield/Storm (Shappell & Neri, 1992), we chose to investigate the effect specific mission types had on aircrew subjective readiness and sleepiness. Several different types of missions were flown during the fleet exercise. However, only those mission types reported five or more times by our pilots were included in this analysis. Using this restriction, eight mission types were entered into the analysis: a) deck-launched intercept (DLI), b) surface search and contact (SSC), c) aircraft carrier qualification (CQ), d) close air support (CS), e) surface combat air patrol (SUCAP), f) launch of aircraft while on alert status (ALTLNC), g) combat air patrol (CAP), and h) air-to-ground strike (STRIKE). The relationship of mission type with aircrew readiness (SSD from the activity survey) and sleepiness (SSS completed pre- and postflight) is illustrated in Figs. 7a and b, respectively. Mission type has been ordered across the abscissa in Fig. 7a as a function of increasing SSD. Mean reported SSD ranged from a low of roughly 0.5 h following DLIs to a high of about 5 h following STRIKEs. The pattern of responses observed here is very similar to that seen by A-6 and F-14 aircrew aboard USS AMERICA during Operations Desert Shield/Storm. The only exception is ALTLNC missions, which were not coded aboard USS AMERICA.

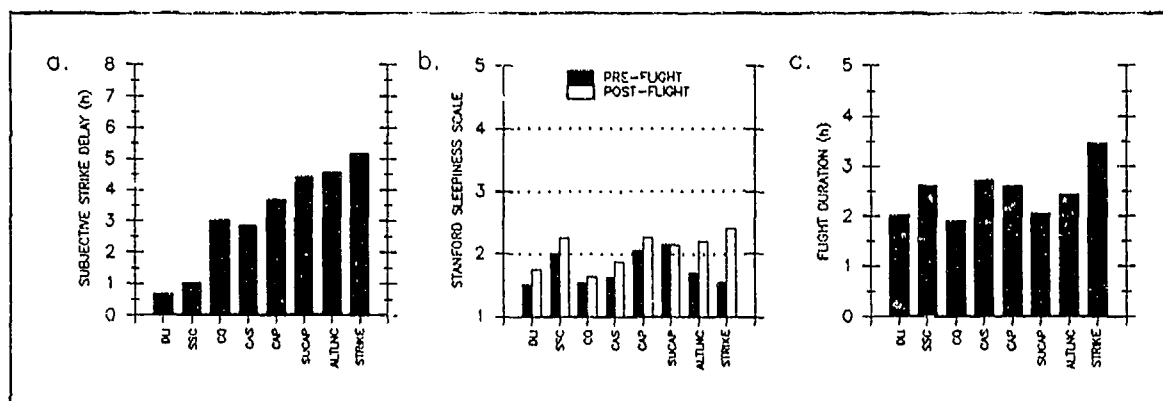


Figure 7. Mean SSD (a), pre- and postflight SSS (b), and flight duration (c) as a function of mission.

The results obtained from the SSS when plotted against mission type for both pre- and postflight periods did not demonstrate the same pattern of increasing sleepiness with mission type observed in reported SSD (Fig. 7b). There was no a priori reason why preflight SSS scores would vary among mission type. Nonetheless, variability did exist, presumably due to other work/rest and flight parameters such as those described above. As before, reported sleepiness postflight was generally greater than that reported during preflight. Responses averaged between 1 *feeling active and vital; alert; wide awake* and 3 *Relaxed; awake; not at full alertness; responsive*, with the largest preflight-postflight differences occurring during STRIKE missions.

The data obtained aboard USS AMERICA revealed a strong relationship between the mission type and flight duration when contrasted with reported SSD. Flights with longer reported SSDs were also of longer duration. Parsing out this apparent confound with flight duration was difficult. The data obtained here does not exhibit the same relationship with flight duration as that seen during the Persian Gulf War (Fig. 7c). In fact, no consistent relationship between flight duration and mission type was readily apparent. This may be partially attributable to the duration of flights observed during the fleet exercise, which typically averaged 1.5-4 h, considerably less than those observed with A-6 and F-14 aircrew aboard USS AMERICA during Operation Desert Shield/Storm. Flights of longer duration may have revealed a pattern of results consistent with those observed for SSD.

## MULTIPLE REGRESSION

We used multiple regression techniques to identify which of the seven selected work/rest and flight variables were useful in predicting pilot SSD. A forward step-wise multiple regression was performed with criteria for inclusion in the model being set at ( $p < .10$ ). Table 3 presents the parameter estimates and the standardized estimate (beta weight) for those variables that significantly contributed to the multiple regression model. An examination of the beta weight for each parameter allows for a direct comparison of the relative weight each parameter contributes to the model. For F/A-18 pilot reported SSD, the amount of sleep 12 h before a flight contributes the most to the model (-0.38), followed by the duration of the flight, hours continuously awake, total flight hours 72 h before a flight, flight quartile, total work hours 24 h before flying, and the number and order of flights per day. The number and order of flights per day is somewhat deceiving since pilots never flew more than two flights per day, thereby restricting the range, and artificially reducing its contribution to the multiple regression model. The important finding is that all seven variables contributed to the model. This was not the case for A-6 and F-14 aircrew investigated during Operation Desert Shield/Storm (Shappell & Neri, 1992).

Using the parameter estimates in Table 3, a significant multiple regression for reported SSD was obtained ( $F(7, 68) = 10.242, p < 0.0001$ ) with  $\Delta = 0.714$  and  $R^2 = 0.5132$ . When  $R^2$  is adjusted for the number of variables in the solution (seven), adjusted  $R^2$  is still an impressive 0.4631. Interpreting these results, 51.32% of the variance observed in reported SSD is accounted for by the seven work/rest and flight parameters examined. Given a new sample and these same seven variables, the regression model would predict that at least 46.31% of the variance would be accounted for.

Table 3. Parameter Estimates for Multiple Regression Model.

Variable	Parameter estimate	Standardized estimate	T	p
Intercept	-4.40	0.00	-1.50	0.137
Flight duration	1.34	0.35	4.01	0.002
Flight quartile	0.77	0.22	2.00	0.049
Flights per day	1.41	0.18	1.71	0.093
Sleep prior 12 h	-0.52	-0.38	-2.49	0.015
Flight hours prior 72 h	0.31	0.24	2.71	0.009
Work prior 24 h	0.24	0.19	1.98	0.052
Continuously awake	-0.14	-0.26	-2.06	0.044



## COGNITIVE TESTING

A unique feature of this study was the collection of objective performance data 30 min before and 30 min after a particular flight. The RT and accuracy data obtained from the basic and inverted RT task are presented in Figs. 8 and 9, respectively. An inspection of the data in Fig. 8 reveals no significant difference in RT obtained pre- and postflight on either the basic (panel a) or inverted (panel b) versions of the task. Pilot RT was significantly longer on the inverted relative to the basic version of the task for both pre ( $t(27) = 5.760, p < .0001$ ) and postflight ( $t(27) = 7.322, p < .0001$ ) measures.

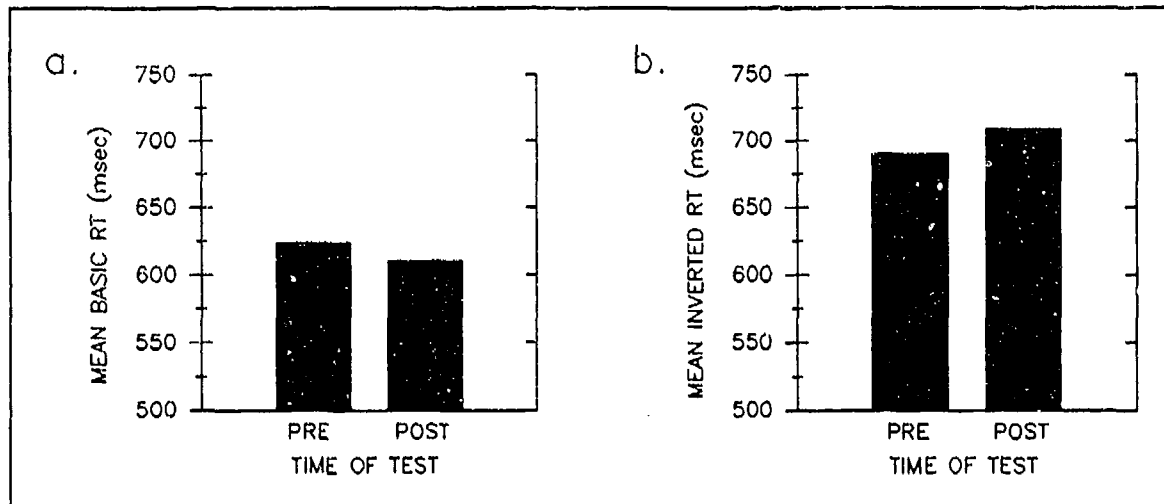


Figure 8. Mean basic (a) and inverted (b) reaction times pre- and postflight.

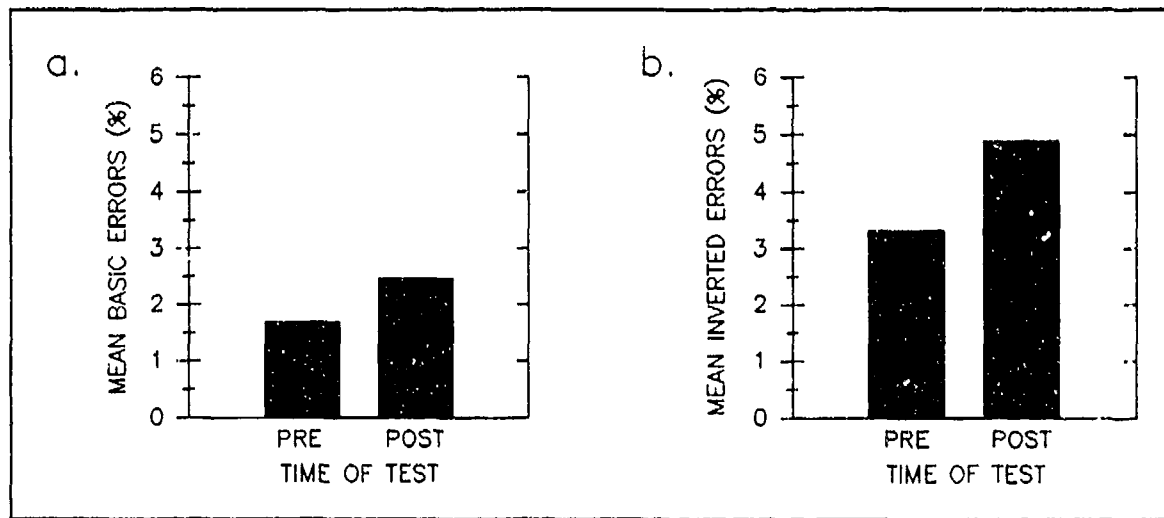


Figure 9. Mean basic (a) and inverted (b) errors pre- and postflight.

Pilot accuracy on each task decreased from pre- to postflight; however, this decline only reached significance on the inverted version of the task ( $t(27) = 2.199, p < .037$ ). The percentage of errors was observed to increase from an average of 1.5-2.5% on the basic task and from approximately 3-5% on the inverted task. As expected, the percentage of errors was significantly greater on the inverted task than the basic task both pre- ( $t(27) = 2.499, p < .019$ ) and post-flight ( $t(27) = 4.138, p < .001$ ).

## DISCUSSION

### DOCUMENTING AIRCREW WORK/REST CYCLES AND THE QUALITY OF CREW REST

Judging from the activity data obtained from the survey, F/A-18 pilots spent roughly 10-12 h per day working and the remainder of the time resting during the fleet exercise. This overall pattern of work and rest is consistent with that seen aboard USS AMERICA during Operation Desert Shield/Storm (Neri & Shappell, 1992). As anticipated, the majority of the time spent working was directed toward duties other than flying and flight-related activities. The tendency to engage in other duties such as mission planning and collateral duties is typical of naval aircrew. Even during the recent Persian Gulf War, aircrew continued to spend several hours per day engaged in work other than flying and flight-related activities. However, even when working a 70-84 h work week, F/A-18 pilots examined during the fleet exercise exhibited no obvious signs of cumulative fatigue.

The general lack of cumulative fatigue may be a function of the quality and duration of crew rest obtained. Pilots typically reported 6-8 h of sleep per night, an amount well within normal limits (Nicholson & Stone, 1987). When questioned regarding the quality of sleep, only slight problems were reported. In general, pilots reported being well-to-moderately rested and reported only a slight need for additional rest. Given this global translation of the data, the work/rest schedules encountered by F/A-18 pilots during this fleet exercise were manageable and conducive to adequate performance both in the cockpit and aboard ship.

Although it is tempting to end the interpretation of the work/rest data here, a closer inspection of the data may reveal trends, that left unnoticed, could undermine the short-term efficiency of the individual pilot. Recall that on days 7 and 8 of the fleet exercise, several pilots reported going to sleep later (0130 rather than 2400) and sleeping less (6 h rather than 7-8 h), relative to the remainder of the fleet exercise. More importantly, only the group means were reported, indicating that several of the pilots reported going to bed even later than 0130 and receiving less than 6 h of sleep. Therefore, many pilots were attempting to sleep between 0300-0900 h and possibly even later. In addition, data obtained from the questions regarding sleep quality reveal that a concomitant elevation in sleep problems existed during days 7 and 8. These crew rest problems are directly related to an increase in flight and flight-related operations, and are consistent with a general increase in operating tempo by the entire airwing during days 7 and 8 of the fleet exercise. A similar but less pronounced relationship between sleep onset, sleep duration, and associated sleep problems was also evident during days 2-4 of the fleet exercise. Therefore, when making assessments of aircrew work/rest cycles, it is important to make more than just global assessments. A more detailed analysis of individual patterns of work and rest on a day-to-day basis may be more revealing.

### IDENTIFICATION OF VARIABLES RELATED TO AIRCREW COMBAT READINESS

Aircrew combat readiness is central to mission success, and as such, is of vital interest to battle group and airwing commanders, squadron commanding officers, flight surgeons, and ultimately those aircrew participating in the mission. Precisely what variables significantly affect combat readiness are often determined using anecdotal reports and experiential factors rather than quantitative means. Our earlier work aboard USS AMERICA identified several variables proven quantitatively to affect aircrew combat readiness as measured using reported SSD (Shappell & Neri, 1992).

Our data collection during the Persian Gulf War was limited to A-6 and F-14 aircrews, but the variables affecting aircrew combat readiness in those aircraft should apply to other aircraft as well. We compared data from the F/A-18, a dual-purpose fighter/attack aircraft, to those variables that proved useful in predicting SSD for F-14 (fighter) and A-6 (attack) pilots during the Persian Gulf War (Figs. 10 & 11, respectively).

When the F/A-18 data obtained here were partitioned by flight quartile, the results were consistent with A-6 (Fig. 10a) and F-14 (Fig. 11a) pilot SSD. That is, both pre- and postflight SSS and SSD were greatest during the fourth flight quartile (0001-0600 h), a time when most aircrew would normally be asleep. Small differences did exist between the three groups (F/A-18, A-6, and F-14 pilots) for the first two flight quartiles. However, the third flight quartile (1801-2400 h) was second only to the fourth flight quartile in reported SSD and postflight SSS scores for all three groups. Although the magnitude of change varied between groups, the data clearly support the assertion that aircrew flying at night (third and fourth flight quartiles) require longer periods of crew rest and are more fatigued/sleepy on mission completion.

Particularly interesting to battlegroup and airwing commanders is the effect multiple missions have on aircrew. Many combat scenarios allow little time for aircrew to recover from one combat mission before a second mission is required. During Operation Desert Storm, A-6 and F-14 aircrews were extremely well managed with care given to the number and type of successive missions flown (Shappell & Neri, 1992). Although there were several instances where two missions were flown in one 24-h period, rarely were both missions of long duration over hostile enemy territory. Rather, these flights were short-duration flights in defense of the carrier battlegroup (e.g., CAP) or in support of other combat elements (e.g., refueling tanker). This may partially explain the lack of any increase in reported SSD from the first to the second flight of the day from F-14 aircrew (Fig. 11b). Nonetheless, for F/A-18 aircrew during the fleet exercise and A-6 pilots during combat, reported SSD did increase following the second mission. In fact, reported SSD for the second flight was nearly twice that of the first (exceeding 6 h for F/A-18 and 11 h for A-6 pilots). Had aircrew been asked to fly a third combat mission before their estimated SSD had expired, mission effectiveness may have been sacrificed. Postflight SSS scores obtained from the F/A-18 pilots increased in a similar fashion, reaching states of *not at full alertness*, a condition potentially hazardous to the pilot and others.

A strong relationship between flight duration and reported SSD was observed for A-6 (Fig. 10c) and F-14 (Fig. 11c) aircrews aboard USS AMERICA. A similar increase was observed for F/A-18 pilots here. As anticipated, no consistent variation in preflight SSS scores was evident when plotted against flight duration. As flight duration increased from 1 to 5 h, reported fatigue for both the postflight SSS scores and reported SSD increased as well. Only small differences in the magnitude and range of flight durations and slope of the relationship were observed between the three groups of pilots. For example, F/A-18 pilots never exceeded flights of 5 h during the fleet exercise, while both A-6 and F-14 pilots reported flights in excess of 5 h on several occasions. The narrow range of flight duration observed in F/A-18 pilots may explain the lack of a well-defined, less steep slope in the relationship between flight duration and SSD and postflight SSS measures. Had F/A-18 pilots experienced a broader range of flight durations, a steeper and more defined slope may have been evident. With such a narrow range of flight durations observed, the tendency is to extrapolate the findings for F/A-18 pilots beyond the 5 h reported here. However, we do not recommend doing so, since the relationship between flight duration and postflight SSS and SSD may be artificially less steep due to the limited range of flight durations, and may therefore yield unreliable results.

The number of hours flown in the past 24/48 h has been related to class A flight/flight related aircraft mishaps in the U.S. Navy/Marine Corps (Borowsky & Wall, 1983). Both the Navy and Marine Corps have established rigid crew rest requirements and limits to the total number of flight hours aircrew can accrue in a 24-h, 1-week, and 1-month period. A preliminary assessment of the F/A-18, A-6, and F-14 data did not reveal a relationship between the number of hours flown in the past 24/48 h with SSD; however, it did if that window was extended to 72 h before flying. At least for F/A-18 pilots, reported SSD was observed to increase as the number of flight hours increased 72 h before flying. A similar relationship was evident for SSS scores. A positive, yet less consistent, relationship existed for A-6 pilots (Fig. 10d) and was essentially

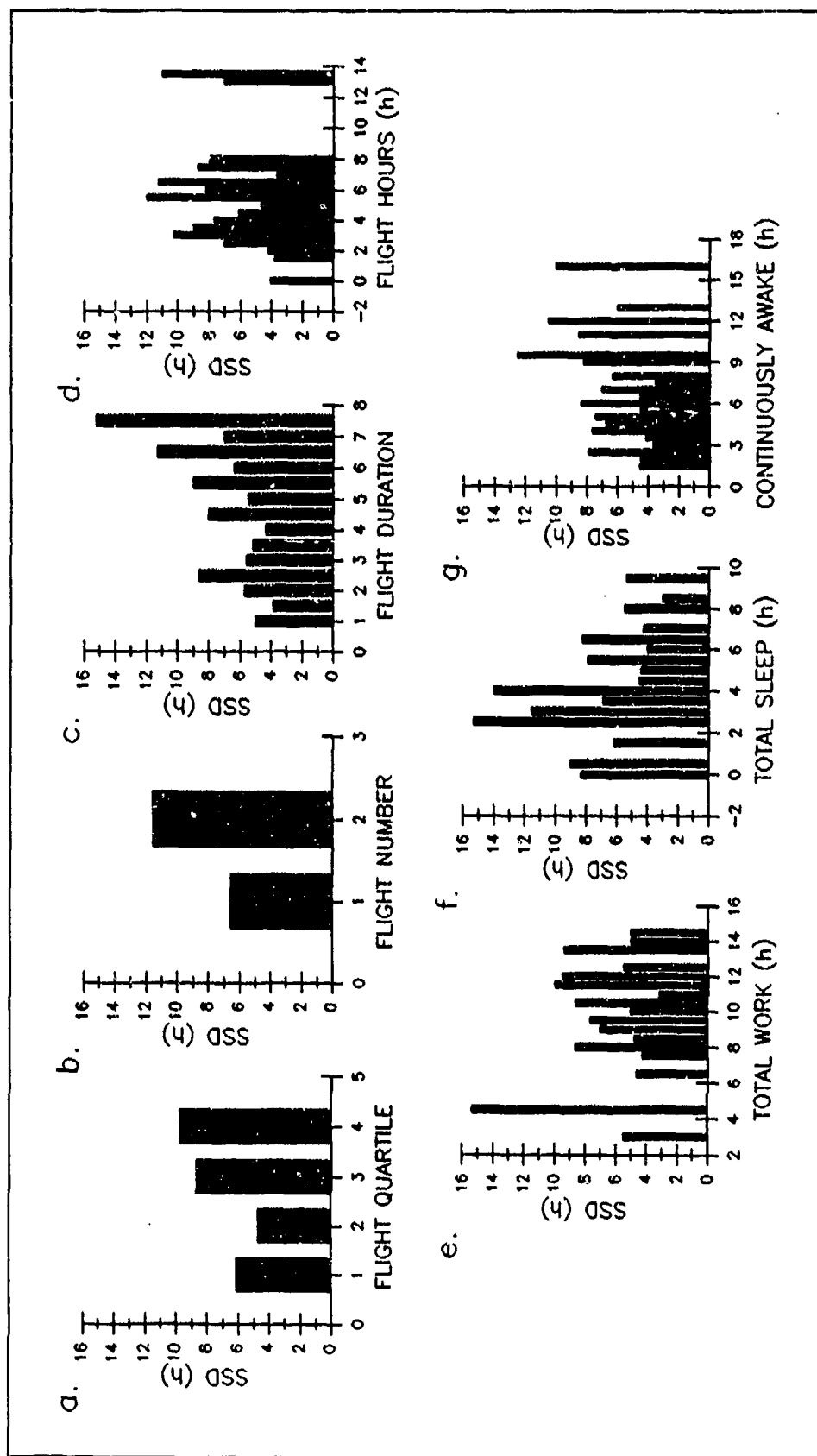


Figure 10. Mean SSD for A-6 pilots (USS AMERICA) plotted by variable.

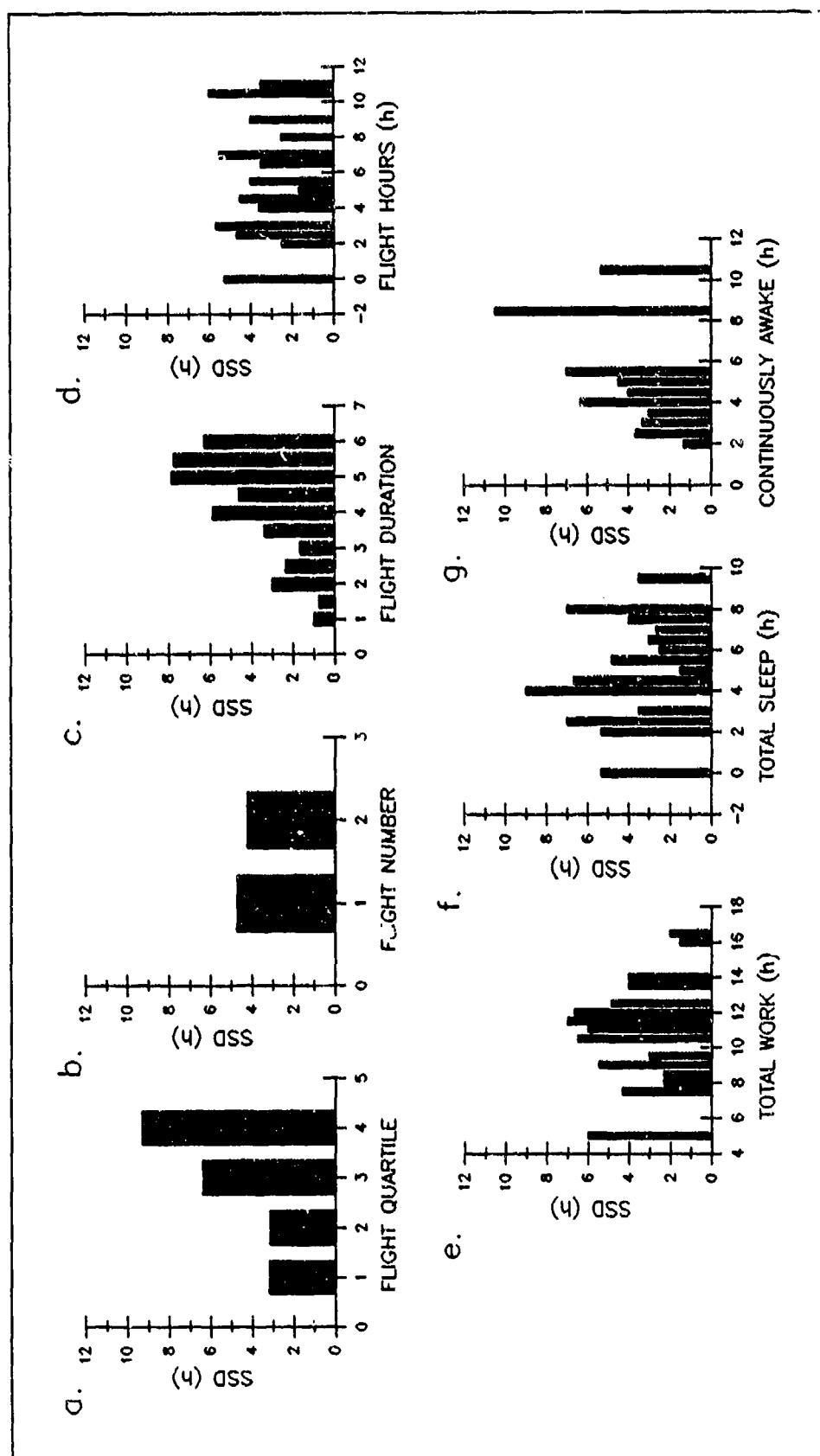


Figure 11. Mean SSD for F-14 pilots (USS AMERICA) plotted by variable.

nonexistent for F-14 pilots (Fig. 11d) observed during the Persian Gulf War. The differences between groups may be explained by comparing the missions flown during the Persian Gulf War and during a fleet exercise with those flown during normal training conditions. Of the three groups, A-6 pilots typically fly longer duration missions (2-5 h) during training, followed by F-14 pilots, and F/A-18 pilots who only fly (1-2.5 h) training missions. In this sense, A-6 and to a lesser extent F-14 aircrews, may be better suited to accumulate more flight hours in a 72-h period. While eight flight hours in a 72-h period may be manageable to A-6 and F-14 pilots, the same number of flight hours in a 72-h period may equate to several missions and be particularly taxing on the F/A-18 pilot. In essence, it's like comparing the distance runner (A-6 pilot) to the middle distance runner (F-14 pilot) and sprinter (F/A-18) in a marathon. Clearly the distance runner (A-6 pilot) will be better suited to the accumulation of miles than the sprinter (F/A-18 pilot). The observed differences may also be a function of dual-seat versus single-seat aircraft. Both A-6 and F-14 aircraft are manned by a pilot and naval flight officer (bombardier/navigator in the A-6, radar intercept officer in the F-14), who share the workload. In contrast, the F/A-18 is manned only by a pilot meaning that all tasks must be completed by one individual, thereby doubling the workload. The increased workload in the F/A-18 may reduce the number of flight hours that can be safely managed in a 72-h period. Such findings, if replicated, are essential when determining crew rest and flight hour requirements on an aircraft-by-aircraft basis, not across all aircraft as is now the case.

Of the seven variables that Borowsky and Wall (1983) related to naval class A flight/flight-related aircraft mishaps, only the number of hours worked 24/48 h before flying reached significance. A general increase in reported SSD with the number of hours worked was evident for F/A-18 pilots during the fleet exercise. The relationship was much less consistent for the A-6 (Fig. 10e) or F-14 (Fig. 11e) pilots examined during the Persian Gulf War. Moreover, no consistent relationship between the amount of time spent working 24 h before flying and sleepiness was evident during the fleet exercise. It is convenient to assert that combat aircrews are not, and should not, be required to complete the numerous collateral and nonflight-related duties present during peacetime training exercises. However, the data obtained during the Persian Gulf War indicates that the amount of time spent engaged in work other than flying and flight-related duties did not appreciably decline (Neri & Shappell, 1992). Exactly why the relationship existed between the total amount of work 24 h before flying and reported SSD for F/A-18 pilots during a fleet exercise and not A-6 and F-14 pilots during combat remains unclear. Further data are required to evaluate these apparent differences.

The amount of sleep before a flight may influence aircrew performance and has been implicated as a causal factor in several Navy/Marine Corps aircraft mishaps (Borowsky & Wall, 1983). Our investigation during Operation Desert Shield/Storm investigated sleep 6, 12, 18, and 24 h before a flight. Only the amount of sleep 12 h before a flight proved significantly related to pilot SSD. Consistent with data obtained from A-6 pilots (Fig. 10f), reported SSD obtained from F/A-18 pilots decreased as the total number of hours slept 12 h before flying increased. In fact, the relationship was much clearer for the F/A-18 pilots. Curiously, F-14 pilots (Fig. 11f) did not demonstrate a similar relationship with that seen for A-6 pilots during the war or F/A-18 pilots during the fleet exercise. Intuitively, reported SSD should decline as the amount of time spent sleeping before a flight increases. However, any conclusions derived from these results are much more complex than the data would suggest. First, due to the limited sample size, we were unable to separate the effect other variables (i.e., flight duration, flight quartile, etc.) had on reported SSD from that of sleep. All seven variables examined were related to SSD in some manner, but the extent to which our results can be attributed to them and how much can be attributed to the amount of sleep before a flight is difficult to assess. Second, aircrew assigned to late night missions (2400-0600) may have attempted to shift their normal sleep regime in preparation for their flight. In doing so, they may have attempted to sleep earlier in the day. The quality of that sleep, because it occurs at a circadian peak, may be less than optimal. Nonetheless, it is still recorded as sleep with no indication of its quality. Third, the bulk of the data was obtained from well-rested aircrew. The results may have been considerably different had the data been obtained from more fatigued pilots. Although preliminary, this observation warrants further investigation, which may be useful in assessing crew rest requirements.

Although not completely independent of the total work and total sleep variables discussed earlier, the total hours pilots spend awake before flying was included because it continues to be an issue during Navy/Marine Corps aircraft mishap investigations. Of the seven variables examined, the number of hours continuously awake before flying is the most variable within and between the three groups of pilots. It appears that F/A-18 and F-14 pilots (Fig. 11g) reported increasing SSD as the hours continuously awake increased, while the relationship was less consistent for A-6 pilots (Fig. 10g). Unfortunately, this variable is much more complex than would appear on the surface. Intuitively, it is expected that the longer you are continuously awake before a flight, the higher reported SSD would be. However, this may not be the case. For example, pilots flying in the late afternoon, a time when reported SSD is relatively low (see above), have typically been awake in excess of 10 h (assuming a 0700 wake-up and flying at 1700). At the end of the mission, reported SSD may be artificially low due to known circadian effects. In contrast, pilots participating in early-morning flights would be awake presumably for only 4-5 h, yet by waking up earlier than normal (e.g., 0400), may suffer from mild sleep deprivation or residual sleep problems and artificially inflate reported SSD. It may be that this variable is only important when the time spent awake exceeds many hours (e.g., 24 h). This and other apparent confounds are difficult to solve. However, the number of hours spent continuously awake before flying remains an important variable in predicting pilot SSD, as was demonstrated using multiple regression techniques discussed below.

### **EFFECT OF MISSION TYPE ON AIRCREW COMBAT READINESS**

The seven work/rest and flight variables discussed in detail above are common to pilots flying all aircraft. Where pilots differ between airframes is the type of combat missions flown. The A-6 pilots typically fly inflight refueling/tanking (TNK), air-to-ground strikes (STRIKE), and TNK missions that accompany the STRIKE package. On the other hand, F-14 pilots fly traditional fighter missions like CAP, CAPs designed to provide protection to high value assets, missions using the tactical air reconnaissance pods system (TARP) to assess bomb damage of enemy positions, a dual TARP and fighter escort mission, missions designed to seek and destroy enemy fighter aircraft commonly called MIG sweeps, and fighter support of air-to-ground STRIKES. The F/A-18 is a hybrid of the A-6 (attack) and F-14 (fighter), engaging in missions common to both communities. The diversity among aviation communities makes any assessment of reported SSD and SSS scores incomplete without some form of mission analysis. When this is done for F/A-18 pilot reported SSD, a pattern similar to that seen for A-6 and F-14 pilots flying the same missions emerges.

The two most difficult missions flown by F/A-18 pilots deserve particular attention. First, STRIKE missions are the most difficult and require the greatest amount of crew rest upon completion. Those flown by F/A-18 pilots are a combination of the attack role of the A-6 pilot (engaging in air-to-ground STRIKES) and the fighter role of the F-14 pilot (engaging in air-to-air support of the STRIKE). Mentally and physically, this dual role is arguably the most demanding of any mission. Second, ALTLNC missions closely follow STRIKE missions in difficulty, not so much in the type of mission flown as the 'front-loading' of fatigue associated with the mission. Pilots in a alert status are required to either be manning the aircraft (as is the case when the pilots are manning an Alert-7, which requires the pilot to launch from the aircraft carrier within 7 min, or an Alert-15, which requires the pilot to launch within 15 min), or standing by in full flight gear in the pilots' ready room awaiting further instructions (as is the case when pilots are manning an Alert-30 or Alert-60). The physical and mental fatigue, though largely undocumented, can be sizable. For example, during an Alert-7, pilots are strapped into a relatively uncomfortable seat, with poor air conditioning and a sizeable environmental drain of their physical resources. Mentally, these pilots must be able to launch within 7 min into imminent danger in defense of the carrier battlegroup. Such stressors only serve to amplify the front-loaded fatigue already present due to other factors as described above.

### **PREFLIGHT/POSTFLIGHT DIFFERENCES IN COMBAT READINESS**

A unique feature of the SSS relative to the SSD was that it was given both pre- and postflight, allowing a more direct evaluation of the fatiguing nature of a specific flight. When differences did exist they were

nearly always in the direction of greater sleepiness postflight relative to preflight levels. Moreover, the largest differences in pre- and postflight scores were observed for STRIKE and ALTLNC missions. Pre- and postflight differences observed for other missions were small, but always in the direction of greater sleepiness postflight relative to preflight levels. The small difference observed for the other missions may be more a function of the relatively low number of flights in each mission category. Perhaps with a larger data set (obtained from future fleet exercises) a more accurate description of the fatiguing nature of specific missions can be acquired.

#### DIFFICULTY REMAINING AWAKE IN THE COCKPIT

Based on our experience during the Persian Gulf War, we felt that item 6 of the activity survey would be particularly revealing. Unfortunately, this was not the case. Rather than eliminate the item in future surveys, it is quite possible that aircrew simply were not fatigued as much as those observed during the Persian Gulf War. This assertion is supported by a comparison of the magnitude of responses obtained from A-6 and F-14 pilots during the war to those obtained from F/A-18 pilots during the fleet exercise. On the average, reported SSDs from A-6 pilots were 2 h longer than F-14 pilots who reported SSDs 2-h longer than F/A-18 pilots. Moreover, the lack of trouble remaining awake while flying is probably a function of many factors. For example, at least for F/A-18 pilots, the fleet exercise was extremely well-managed, with specific attention being paid to the scheduling of flights. Pilots typically flew only one flight per day, and when a second flight was scheduled, it was usually separated by an adequate time to obtain additional crew rest prior to launching. The exception to this was in the case of standing by inside the alert aircraft as described above. A second reason why there were few reports of trouble staying awake in the cockpit may have to do with the type and duration of flights these pilots engaged in. Unlike the pilots examined during the Persian Gulf War, most of the flights observed here were shorter duration, requiring minimal time in transit to the aircraft carrier, and waiting in a holding pattern to land aboard the aircraft carrier, a period during which a majority of the anecdotal reports of trouble staying awake in the cockpit centered around. Additionally, these were highly motivated pilots flying a single-seat aircraft, which is very unforgiving of mental errors due to fatigue since there is no one in the aircraft to back-up the pilot. This may have also contributed to the general lack of reports of trouble remaining awake in the cockpit.

#### QUANTIFICATION OF VARIABLES RELATED TO F/A-18 PILOT COMBAT READINESS

Multiple regression techniques provide a quantitative means of determining which variables are significantly related to the prediction of reported SSD. For F/A-18 pilots, 51% of the variance in reported SSD is accounted for by the seven selected work/rest and flight variables described in detail above. The percentage of variance accounted for in our sample is extremely good relative to that commonly reported in the psychological literature. Overall, the multiple regression model derived provides additional support for those variables identified as determinants of SSD. The remaining 49% of the variance in reported SSD may be from sources not easily accessible to the investigator, like motivation, physical and mental fitness, or other personality factors. As additional variables are related to reported SSD, they can be incorporated into the multiple regression model. The search for these additional pools of variance should be included as a principle goal of future studies.

Multiple regression techniques also enable the investigator to quantitatively establish the relative weight each of the significant variables exerts in determining reported SSD. In this way, a mathematical model can be formed to aid in the prediction of crew rest requirements following a given flight. Using the parameter estimates listed in Table 3, the following model was derived:

$$\text{SSD} = 1.34 (\text{flight duration}) + 0.77 (\text{flight quartile}) + 1.41 (\text{flights per day}) - 0.52 (\text{sleep prior 12 h}) + 0.31 (\text{flight hours prior 72 h}) + 0.24 (\text{work prior 24 h}) - 0.14 (\text{hours continuously awake})$$



Such a model requires much more data for validation than was collected during the fleet exercise and should be viewed with caution. Even so, it does provide an initial step in the development of a prediction model that can aid those individuals integral in scheduling aircrew assets.

#### **EVALUATION OF PILOT PERFORMANCE USING OBJECTIVE MEANS**

Subjective inventories like the SSS are often criticized because they rely on an individual's personal assessment of his/her abilities and do not provide an objective means of evaluating performance. However, the data obtained here using an objective reaction time task lend additional support to our previous data using SSD and SSS scores. Although the sample was a subset of the pilots in the larger study (due to the lack of computer assets to administer the task), it does provide some valuable information. Pilot reaction time was relatively unaffected by the flight, while error rate increased. In particular, when confronted with the inverted task (a more difficult variation of the basic RT task), error rate significantly increased to 5%, a 2% increase over preflight measures. Such increases may seem trivial when viewed from the laboratory perspective, but the naval aviation environment is very unforgiving. A 2% error in landing aboard an aircraft carrier or when delivering ordnance can be catastrophic.

Additional objective data are required from fleet aviators. The use of objective, computer-administered cognitive batteries pre- and postflight was originally deemed too difficult to do, primarily due to space considerations on the aircraft carrier, as well as time constraints and the commitment required of aviators to complete the battery before and after flying. We have demonstrated that given the cooperation of the squadron these difficulties can be overcome.

#### **SUMMARY**

This initial investigation conducted during a fleet exercise, and our investigation of A-6 and F-14 aircrew during Operation Desert Shield/Storm provide the necessary first steps in future research endeavors aboard operational aircraft carriers. As expected, the data reported here during a fleet exercise are consistent with that observed during combat. However, before extrapolating our findings to all aviators in most situations, further research efforts are required. We recommend that the data obtained here be considered with data obtained during additional fleet exercises and contingency operations as the opportunities arise. When used in conjunction with existing experiential and qualitative judgments by individuals charged with determining aircrew readiness--battlegroup and airwing commanders, squadron commanding officers, senior mission planners, and flight surgeons--our data should prove useful in improving the safety of flight.

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#### Other Related NAMRL Publications

- DeJohn, C.A., Shappell, S.A., & Neri, D.F. (1992). *Subjective fatigue in A-6, F-14, and F/A-18 aircrews during Operations Desert Shield and Desert Storm* (NAMRL-1377). Pensacola, FL: Naval Aerospace Medical Research Laboratory.
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